inclination of the transfer curve becomes steep (that is, Hs becomes small), and the MR ratio decreases. As a result, ΔV becomes small. From Fig. 7A and Fig. 7B, known are the two problems noted above.

Of the two problems, one relating to the bias point could not be recognized with ease even though the film structure is determined. Therefore, film structure designing was extremely difficult. This time, we, the present inventors carried out various simulations, and corrected the errors in the data we obtained, on the basis of our experiences. As a result, we have succeeded in correct judgment of the bias point. The calculation of the bias point is mentioned below.

The bias point is shifted by various external magnetic fields applied to the free layer. The shift could approximate the sum total of (1) current magnetic field (Hcu), (2) the static magnetic field from the pinned layer (Hpin), (3) the interlayer coupling magnetic field from the pinned layer via a spacer (Hin), and (4) the stray magnetic field (Hhard) from the hard bias film for the purpose of imparting a longitudinal bias to the magnetoresistance effect film. Of those magnetic fields (1) to (4), the hard bias magnetic field (4) is relatively small. Having noted the sum of the magnetic fields (1) to (3), we, the present inventors have assiduously studied. The calculation formulae for the bias point which we employed this time are mentioned below.

$$\text{B.P.} = 50 \times (\text{Hshift}/\text{Hs}) + 50 \qquad (1\text{-}1)$$

$$\text{Hshift} = -\text{Hin} + \text{Hpin} \pm \text{Hcu} \qquad (1\text{-}2)$$

$$\text{Hs} = \text{Hd}^{\text{free}} + \text{Hk} \qquad (1\text{-}3)$$

$$\text{Hd}^{\text{free}} = \pi^2 (\text{Ms} \times \text{t})_{\text{free}}/\text{h} \qquad (1\text{-}3\text{-}1)$$

$$\text{Hpin} = \pi^2 (\text{Ms} \times \text{t})_{\text{pin}}/\text{h} \qquad (1\text{-}4)$$

$$\text{Hcu} = 2\pi C \times I_s/\text{h} \qquad (1\text{-}5)$$

$$C = (I_1 - I_3)/(I_1 + I_2 + I_3) \qquad (1\text{-}5\text{-}1)$$

B.P. to be represented by the formula (1-1) is the bias point [%] to be specifically noted herein. The best bias point is 50 %. Including the margin, the practicable range of the bias point will fall between 40 and 60 %. If the bias point oversteps the range, asymmetric signals will be formed. In worse cases, no output could be obtainable.

Regarding the relationship between the bias point value and the asymmetry, the asymmetry will be +10 % or so when the bias point is 40 %, and it will be -10 % or so when the bias point is 60 %. As will be mentioned hereunder, the best bias point in calculation does not fall between 40 and 60 %, but falls between 30 and 50 % in experiences.

Fig. 8 is a graph of calculated bias point values versus head reproducing signal waves. As shown, when the bias point falls between 30 and 50 %, the asymmetry is relatively small, and the signal profiles are good. However, when the bias point is outside the range, the asymmetry becomes great, as in Fig. 8, and the signal profiles are not practicable.

As in the formula (1-2), Hshift, is the sum of the magnetic fields [Oe] applied to the free layer. As in Fig. 7, Hs is the inclination of the transfer curve.

Fig. 9 is an explanatory view indicating magnetic fields acting on the free layer.

Hd^{free} is an antimagnetic field for the free layer at a certain MR height. h is the MR height [μm]. Hpin is the pinned layer stray magnetic field from the pinned layer to the free layer. $(Ms \times t)_{free}$ is the product of the total saturation magnetization, Ms, and the thickness, t, of the free layer. $(Ms \times t)_{pin}$ is the product of the saturation magnetization and the thickness of the net pinned layer (for Synthetic AF, the difference in the magnetic thickness between the upper and lower pinned layers).

Hcu is the current magnetic field applied to the free layer. Is is the sense current [mA]. The coefficient, C, in the formula (1-5-1) is the ratio of the partial current flow running through the upper layer overlying the free layer to that running through the lower layer underlying it.

Fig. 10 is a conceptual view indicating the partial current flows I_1 to I_3 running through the layers.

For simplifying the calculation, the influences of the edges of the ABS plane and those of shields are not taken into consideration. In our experiences, we, the present inventors have found that the bias point values as estimated in

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